A Simulated Drilling Mission to Search for Biomolecular Signatures of Life on Mars Performed in the Atacama Desert (Chile): Demonstrating Drilling, Sample Handling, and Life-Detection Instruments Remotely Operated with Mission-like Protocols

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Introduction: The search for evidence of life on Mars requires accessing materials that are protected from the oxidizing and irradiated conditions at the surface. Mars rovers Curiosity and Perseverance have performed shallow (few cm) drilling to access relevant samples. The upcoming ExoMars mission will acquire samples from up to 2 meters depth. Field experiments in Mars analog sites help prepare for this and other future deep drilling missions. In Sept. 2019 the ARADS (Atacama Rover Astrobiology Drilling Studies project (Glass *et al*. 2022) conducted a rover-based drilling mission to search for biomolecular evidence of life in a Mars analog site in Atacama Chile.

Methods: The KREX rover (Figure 1A) carried a 1-meter TRIDENT (The Regolith and Ice Drill for Exploration of New Terrains) drill and a robotic arm and scoop to deliver subsurface materials to two deck-mounted flight-prototype instruments: 1) The Signs of Life Detector (SOLID) a protein and biomolecule analyzer based on Fluorescence Sandwich Microarray Immunoassay [Parro *et al.* 2011]; and 2) MILA (Microfluidic Life Analyzer) that analyzes samples for amino acids with chirality differentiation using Subcritical Water Extraction (SCWE) [Kehl *et al.* 2019] coupled to Microchip Electrophoresis with Laser Induced Fluorescence (ME-LIF) [Mora *et al.* 2020].

The field site and sampling targets were selected by a California-based Remote Science Team (RST) using Google Earth and on-site drone images that showed a light-toned basin surrounded by a higher darker-toned flat region (Figs. 1B, 1C). The RST sent daily commands to the Chile-based field team to direct the drill, arm, and instruments operations. They daily received and analyzed instrument results and refined the next day's plans in response.

Results: Drilling up to 80-cm depth was accomplished in three areas separated by c.a. 50-100 meters, two within the basin and one in the surrounding dark toned desert soil. The SOLID and MILA instruments detected biosignatures in basin samples collected at depths ranging from 20 to 80-cm and did not detect them in the desert floor area outside the basin [Mora *et al.* 2020, Moreno-Paz *et al.* 2022]. Results from the two instruments were consistent where the same samples were analyzed. Subsurface stratigraphy was interpreted from drill telemetry sensor data as fine-scale layers of sand/clay sediments interspersed with layers of harder material in the basins and a uniform subsurface composed of course-to-fine sand outside the basin. To characterize operational complexity, the mission timeline and number of commands sent to accomplish each activity were tracked. The deepest borehole (80 cm) required 58 commands sent by a remote operator including drilling, sample collection and delivery to three instruments with a total elapsed time of 2.05 hours.

The mission successfully detected biomolecular evidence of life in one of the most extreme and biologically sparse environments on Earth. Results are relevant to planning for ExoMars and VIPER missions that use comparable drilling systems.

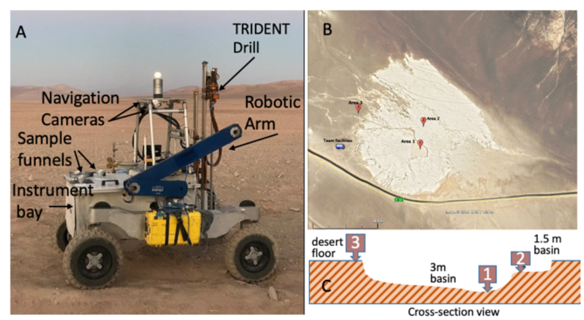

Figure 1. (A) Robotic system. (B) Field site showing drilled locations. (C) Topography where samples collected.

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